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(54) **Printed circuit board including crosstalk compensation**

(57) Disclosed is a device for reducing crosstalk in an electrical connector. The device includes an insulating board with a plurality of layers. A first plurality (T_1, R_1;T_3,R_3;T_5,R_5) of pairs of conductive paths is formed on a surface of at least one layer, and a second plurality (T_2,R_2;T_4,R_4) of pairs of conductive paths is vertically spaced therefrom. The paths are arranged so that at least one conductive path in the first plurality (T_1,R_1,T_3, R_3;T_5,R_5) of pairs overlies at least two conductive paths from different pairs in the second plurality (T_2,R_2;T_4,R_4) of pairs. The capacitive coupling between the paths results in crosstalk having a polarity opposite to that of the connector so as to compensate for the connector crosstalk.

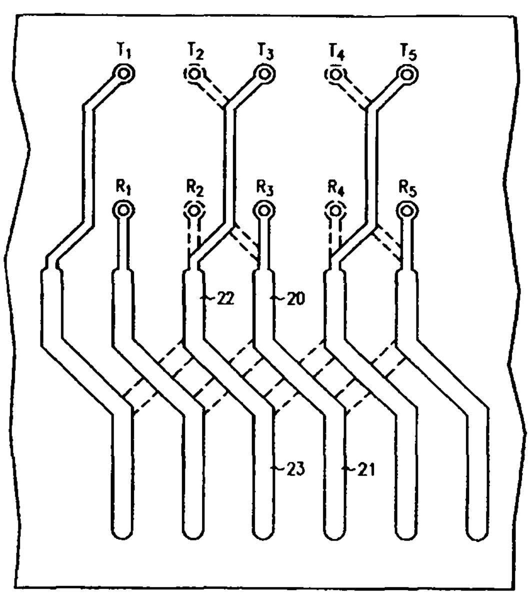

FIG. 4

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Description

Field of the Invention

This invention relates to electrical connectors and in particular to a structure for reducing crosstalk in connectors.

Background of the Invention

Standards for crosstalk in connectors has become increasingly stringent. For example, in category 5 of ANSI/TIA/EIA - 568A Standard, it is required that a 25 pair ribbon cable connector exhibit near-end crosstalk which is less than 40dB at 100 MHz using the standard power sum measurement, which is the sum of crosstalk from all the pairs of the connector.

Recently, it has been proposed to produce a category 5 connector by inclusion of conductors in a side-by-side relation to provide crosstalk of a polarity opposite to the mating section of the connector. (See U.S. Patent Number 5,562,479.) It has also been proposed to reduce crosstalk, for example in modular jacks, by crossing over certain conductors. (See U.S. Patent No. 5,186,647 issued to Denkmann et al.) It has also been suggested that certain conductors in a modular jack could be mounted above certain other conductors to provide capacitive coupling and thereby induce opposite polarity crosstalk. The conductors could be formed as lead frames or printed on a printed circuit board (See British Patent No.2,271,678 issued to Pinney et al.)

It has also been suggested that a printed wiring board connector could compensate for crosstalk in its mating section by including capacitive coupling unbalance between conductor pairs which produced crosstalk of an opposite polarity. (See, U.S. Patent Application of Conorich, Serial No. 08/673711, filed on June 21, 1996.) Further, a device has been proposed for converting a connector to category 5 performance by providing vertically aligned conductor paths in a multi-layer board such that the paths form capacitor plates which capacitively couple adjacent conductor paths in order to produce crosstalk of a polarity opposite to the connector. (See, U.S. Patent Application of Choudhury, Serial No. 08/668553, filed June 21, 1996.)

Summary of the Invention

The invention is a device for compensating for crosstalk in a connector. The device comprises an insulating board including a plurality of layers. A first plurality of pairs of conductive paths is formed on a major surface of one of the layers. A second plurality of pairs of conductive paths is vertically spaced from the first plurality of pairs. The conductive paths of at least one plurality are arranged in a serpentine configuration such that at least one conductive path in the first plurality of pairs overlies at least two conductive paths from different pairs in the second plurality of pairs. The paths produce crosstalk of a polarity which is opposite to that produced by the connector when a voltage is supplied to the paths.

Brief Description of the Drawing

These and other features of the invention are delineated in detail in the following description. In the drawing:

FIG. 1 is an exploded cross sectional view of an assembly in accordance with an embodiment of the invention;
FIG. 2 is a plan view of one of the layers of the board depicted in FIG. 1;
FIG. 3 is a plan view of a layer adjacent to that shown in FIG. 2; and
FIG. 4 is a superposition of certain features of the layers of FIGs. 2 and 3.

It will be appreciated that, for purposes of illustration, these figures are not necessarily drawn to scale.

Detailed Description

Referring now to the drawings, in which like reference numerals identify similar or identical elements, FIG. 1 illustrates an assembly which will result in reduced crosstalk in accordance with an embodiment of the invention. A standard connector, 10, includes an insulating housing which encloses a plurality of contacts. As known in the art, the contacts are formed as opposite pairs, also known in the art as tip and ring contacts, so that at one end, the contacts form a mating section, 12, for receiving a standard cable connector (not shown). The other ends of the contacts are formed into pins or eyelets, e.g., 13, which are adapted for insertion into corresponding holes (illustrated in FIGs. 2-4) in a printed circuit board, 14. (It will be appreciated that in the view of FIG. 1, only the pins extending from the ring contacts are shown, and the pins extending from the tip contacts are behind the pins of the ring contacts in this view.) In this example, only five tip and ring pairs are shown for illustrative purposes. Typically, the connector, 10, would include many more pairs, such as 25 pairs.

The connector, 10, will produce a certain amount of crosstalk in the form of induced voltages of a certain polarity in the mating section, 12, as a result of the orientation of the tip and ring contacts. Unless some means are provided in the connector for reducing this crosstalk, the connector will usually not provide category 5 performance. However, by virtue of the structure of the printed circuit board, 14, to be described, crosstalk of a polarity opposite to that of the connector can be generated to reduce the overall power sum crosstalk loss to better than 40 dB at 100 MHz.

As illustrated in FIG. 1, the circuit board, 14, includes a plurality of layers, such as 16, which are formed

according to standard techniques and are typically made of an epoxy glass material such as FR-4. The epoxy glass layers are held together by adhesive layers, e.g., 15 and 17, which are also typically made of FR-4. While five layers are shown in this example, it will be appreciated that any number of layers can be employed according to particular needs. The epoxy glass layers typically have a thickness, t, within the range 150 to 7600 microns.

Formed on the two major surfaces of at least one layer, 16, are a first and second plurality of pairs of conductive paths, which paths are designated with a T or an R to indicate electrical connection with corresponding tip or ring contacts in the connector. Thus, as shown in FIG. 2, the top surface of layer 16 includes three pairs of conductive paths, T_1 - R_1, T_3 - R_3, and T_5 - R_5, while the bottom surface of layer 16, as shown in FIG. 3 and viewed from the top of the layer, includes two pairs labeled R_2 - T_2 and R_4 - T_4. Again, the number of pairs is illustrative only, and will correspond with the number of contact pairs in the connector, 10. The conductive paths are typically made of copper and are formed by standard photolithographic techniques to a typical thickness of 35.56 microns. Each conductive path, e.g., R_3, is coupled to a corresponding plated through hole, 18, to provide an electrical connection to the contacts of the connector 10 when the contacts of the connector are inserted in the holes.

In accordance with a key feature of the invention, each conductive path is formed in a serpentine pattern so that certain portions of at least one path will be vertically aligned with at least two paths of another type in another layer. FIG. 4 illustrates the overlap of the various paths, with the paths on the top of layer 16 (T_1 - R_1, T_3 - R_3, and T_5 - R_5) shown in solid lines and the paths on the bottom of layer 16 (T_2 - R_2 and T_4 - R_4) shown in dashed lines. It will be noted for example, that path R_3 has a portion, 20, which overlies a portion, 30, of path T_2, and also has a portion, 21, which overlies a portion, 31, of path T_4. Similarly, path T_3 has a portion, 22, which overlies a portion, 32, of path R_2, and also has a portion, 23, which overlies a portion, 33, of path R_4.

In another feature of the invention, odd numbered pairs of conductive paths reside on one surface of a layer while even numbered pairs of conductive paths reside on the opposite surface of that same layer so that certain portions of at least one path of each pair will be adjacent on the same surface of a layer to certain portions of one path of another type of a next adjacent pair. It will be noted for example, that path R_3 has portions 20 and 21 on surface 16 adjacent to portions 24 and 25 of path T_5 on surface 16. Thus at least one path in a pair will have portions vertically aligned with an unlike path connected to an adjacent pair in connector, 10, and portions adjacent on the same surface with an unlike path connected to a next adjacent pair in connector, 10.

The result of this alignment will be that when the connector is operating and a voltage is thereby applied to the paths, at least selected paths, e.g., R_3, will be capacitively coupled to unlike paths, T_2 and T_4 in two adjacent pairs. This capacitive coupling between unlike paths produces capacitive coupling unbalance between adjacent pairs which results in near end crosstalk which is opposite in polarity to the crosstalk produced in the mating section of the connector, 10. Another result of this alignment will be that when the connector is operating and a voltage is applied to the paths, at least selected paths, e.g., R_3 will be capacitively coupled to an unlike path T_5 in a next adjacent pair. This capacitive coupling between unlike paths produces capacitive coupling unbalance between next adjacent pairs which also results in near end crosstalk which is opposite in polarity to the crosstalk produced in the mating section of the connector, 10. (As understood in the art, the term capacitive coupling unbalance describes the total capacitive coupling between two pairs contributing to differential crosstalk, i.e., the difference between capacitive coupling between unlike conductors in the pairs and capacitive coupling between like conductors in the pairs.) Therefore, by adjusting the capacitive coupling of the paths, the near end crosstalk in the connector can be essentially cancelled, or at least made better than 40 dB at 100 MHz. Further, since the power sum measurement takes into account the crosstalk produced by all pairs, the present arrangement is advantageous in that it provides coupling unbalance between a pair and at least its two adjacent pairs.

Specifically, the crosstalk in the mating section, 12, of the connector, 10, can be measured or calculated according to known techniques. (See, e.g., Application of Conorich, Serial No.08/673711, filed June 21, 1996 which is incorporated by reference herein.) The mutual capacitive unbalance, Cm, and mutual inductance, Lm, between two adjacent pairs in the board 14, e.g., T_3 - R_3 and T_4 - R_4 are given by:

$$Cm = \frac{2\varepsilon_r\varepsilon_o 1a}{t}$$

$$Lm = \frac{\mu_r\mu_o 1}{2\pi} \ln\left[\frac{d^2+t^2}{t^2}\right]$$

where ε_o is the dielectric constant of free space, ε_r is the dielectric constant of the board material (16), t is the thickness of the layer 16, 1 is the length of a straight portion of the paths (e.g., 20, 23), a is the width of the paths, μ_o is the permeability of free space, μ_r is the relative permeability of the board material and d is the horizontal separation between the centerlines of two adjacent paths.

The canceling near-end crosstalk, X, produced by the paths is then:

$$X = \frac{-Zs}{2}\left[j\omega\frac{Cm}{4} + j\omega\frac{Lm}{Zs^2}\right]$$

where the minus sign indicates that the crosstalk is 180 degrees out of phase with the crosstalk produced in the mating section due to the fact that the paths are capacitively coupled to unlike paths in adjacent pairs, and where Zs is the source or load impedance and ω is the angular frequency of the applied signal.

Thus, t, 1, ε_r and a can be chosen so that the magnitude of the crosstalk produced in the board is essentially equal to the magnitude of crosstalk in the mating section. In one example, the length, 1, of the paths was 0.002 meters, the thickness, t, of the layer was 0.00015 meters, ε_r was 4.5, the width of the path, a, was 0.00091 meters, and the horizontal separation between adjacent paths, d, was 0.00216m. A power sum crosstalk of 40dB at the frequency of 100 MHz for the combination connector and board could be obtained by choosing the above parameters.

While the figures show only two layers of conductive paths, it will be appreciated that the board could include several more layers of paths on the major surfaces of the dielectric layers. These additional layers could also provide opposite polarity crosstalk in the manner described or provide other functions such as fanouts.

Claims

1. A device for compensating for crosstalk in a connector (10), the device **CHARACTERIZED BY**:

   an insulating board (14) including a plurality of layers (e.g., 15, 16, 17);
   a first plurality of pairs (T_1 - R_1, T_3 -R_3, T_3 -R_5) of conductive paths formed on a major surface (16) of one of the layers; and
   a second plurality of pairs (T_2 -R_2, T_4 - R_4) of conductive paths vertically spaced from the first plurality, the conductive paths of at least one plurality being arranged in a serpentine configuration such that at least one conductive path in the first plurality of pairs overlies at least two conductive paths from different pairs in the second plurality of pairs, whereby the paths produce crosstalk of a polarity opposite to that produced in the connector when a voltage is supplied to the paths.

2. The device according to claim 1 wherein the second plurality of pairs is formed on an opposite major surface of the layer.

3. The device according to claim 1 further comprising means (18) in said board for connecting the paths to corresponding contacts in the connector.

4. The device according to claim 3 wherein each path in a pair is connectable to a contact in the connector which is of a different type than the other path in the pair.

5. The device according to claim 4 wherein the said at least one conductive path in the first plurality of pairs overlies at least two conductive paths from different pairs in the second plurality of pairs which are connectable to contacts of a different type than the said one conductive path.

6. The device according to claim 4 where the said at least one conductive path of the first plurality of pairs is adjacent to at least one conductive path on the same major surface of the layer which is connected to a contact of a different type than the said one conductive path and which is of a next adjacent pair in the connector.

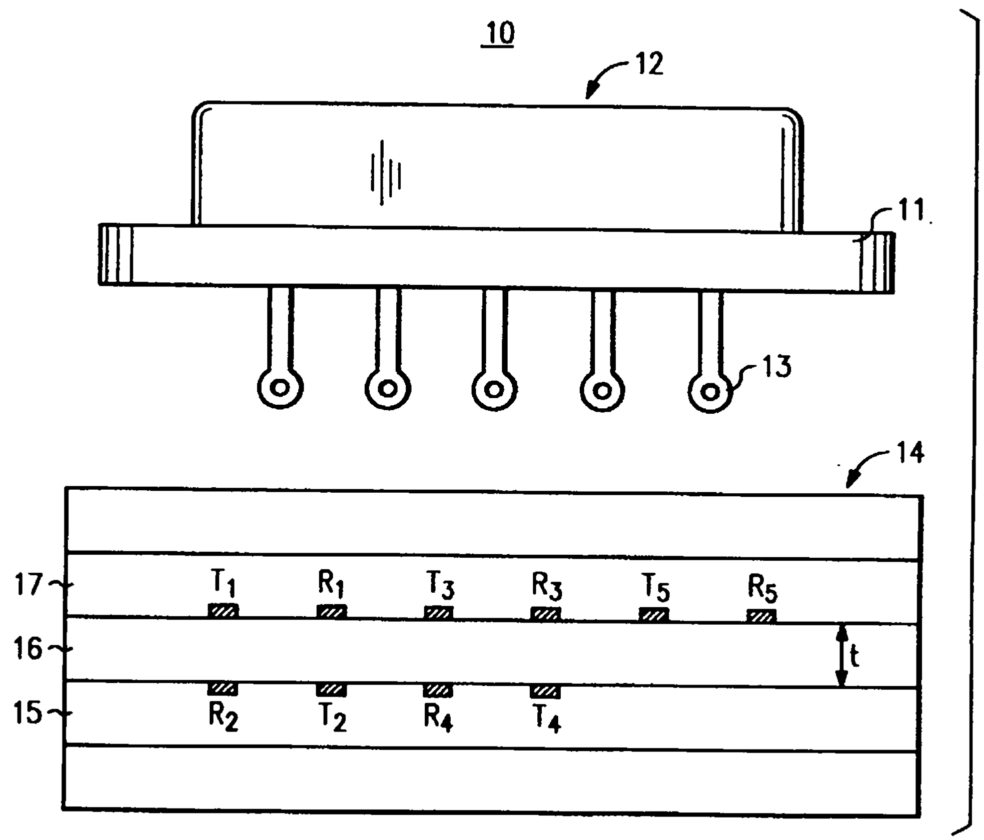

FIG. 1

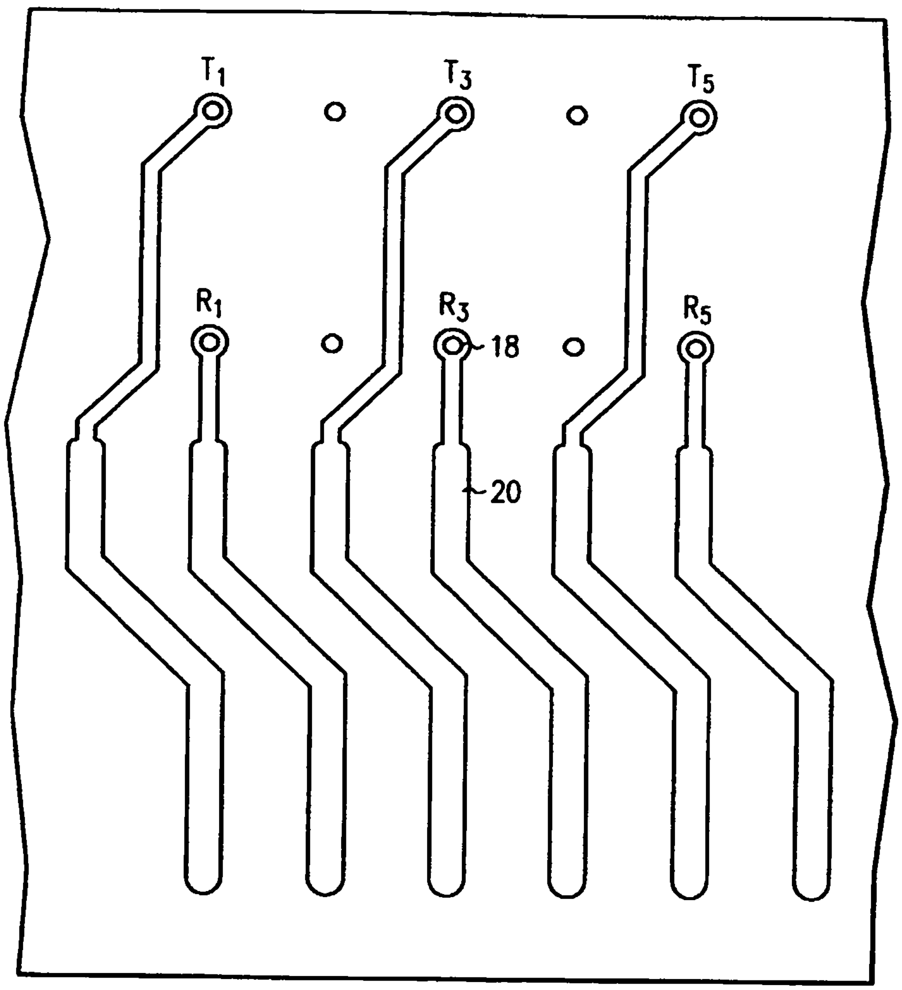

FIG. 2

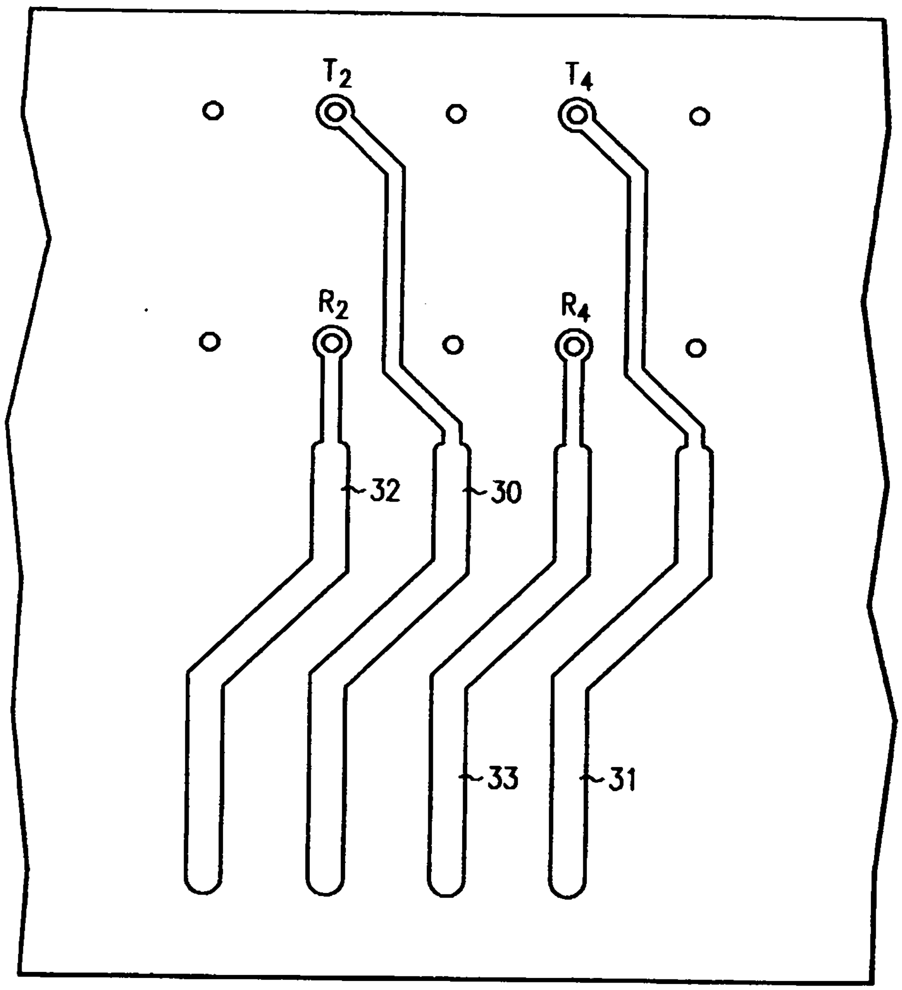

FIG. 3

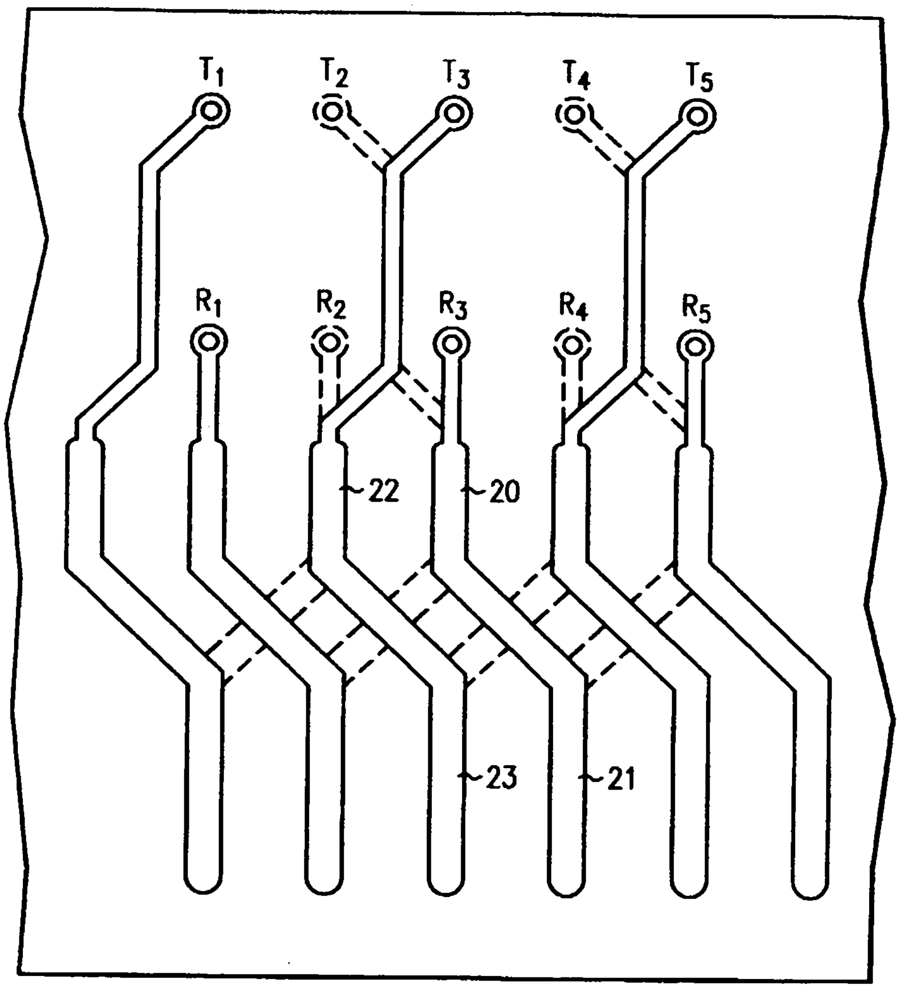

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number EP 98300049.8

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 6)
X A	GB 2269941 A (HUBBELL) 23 February 1994 (23.02.94), fig. 1-8, abstract, pages 10-18, claims.	1-5 6	H 05 K 1/14 H 01 R 13/719
X A	CH 659558 A5 (BBC) 30 January 1987 (30.01.87), fig. 3, page 3, column 2, lines 50-67, claims.	1-3 4-6	
A	GB 2298974 A (HUBBELL) 18 September 1996 (18.09.96), fig. 2,3,5,6, abstract, claims.	1-6	
A	US 5586914 A (FOSTER) 24 December 1996 (24.12.96), fig. 6,10,12,14, column 12, lines 16-27, claims.	1,3,5,6	**TECHNICAL FIELDS SEARCHED (Int. Cl.6)** H 05 K 1/00 H 01 R 13/00
A,P,D	GB 2314466 A (LUCENT) 24 December 1997 (24.12.97), fig. 2,3, abstract, claims.	1-6	
A	EP 0709930 A2 (WHITAKER) 01 May 1996 (01.05.96), fig. 2-4,6-8, abstract, claims.	1-6	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	27-02-1998	KRAL

CATEGORY OF CITED DOCUMENTS

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